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METHODS OF TESTING NATURAL GAS FOR GASOLINE CONTENT

BY

G. A. BURRELL AND G. W. JONES

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METHODS OF TESTING NATURAL GAS FOR GASOLINE CONTENT.

By G. A. Burrell and G. W. Jones.

INTRODUCTION.

The Bureau of Mines is conducting a series of investigations with the common aim of minimizing the losses that occur in the mining and treatment of mineral substances. The results of the investigations are being published in reports of the bureau. This report treats of methods of testing natural gas for gasoline content, and especially discusses those tests that can be used to show the applicability of the compression and condensation process and the absorption process for producing gasoline from natural gas.

THE TESTING OF NATURAL GAS FOR GASOLINE CONTENT.

Before a plant for extracting gasoline from natural gas is erected the yield and quality of the natural gas to be used should be thoroughly investigated. In the early days of the "casing-head" gasoline industry the failure of some plants to fulfill expectations was due to inadequate testing of the gas before construction of a plant was begun. More recently methods of testing natural gas for gasoline have become better standardized, and there is scarcely any excuse for the failure of a plant because of inadequate preliminary tests.

By itself the ordinary combustion method for determining the methane and ethane content of natural gas is of little value for estimating the gasoline content. In addition, it is difficult to perform, and a gas analyst must have had experience in methods of analyzing refined gas before he can make a satisfactory analysis of natural gas, especially casing-head gas. Moreover, this method informs one only of the two predominating paraffins present and gives slight information on the quantity of gasoline vapors. As a result, chemists early turned their attention to other more definite and more easily conducted tests. The laboratory tests that have been adopted and are chiefly used are those for specific gravity and solubility.

SPECIFIC-GRAVITY TEST.

Natural gas may vary in specific gravity from about 0.56 (air = 1) to as much as 1.65, or from a gas containing methane as the only paraffin hydrocarbon, the methane constituting 99 per cent or more

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of the total volume of the gas, to an extremely "wet" gas, from which gasoline in quantities up to 4 or 5 gallons per 1,000 cubic feet can be obtained.

Specific-gravity tests may be made either by weighing the gas in a small glass vessel or by means of the effusion method first proposed by Bunsen. The weighing method is the more accurate, but for testing casing-head gas for its gasoline content sufficiently reliable results can be obtained by the effusion method, and it possesses the advantage over the weighing method that a test can be easily and rapidly made.

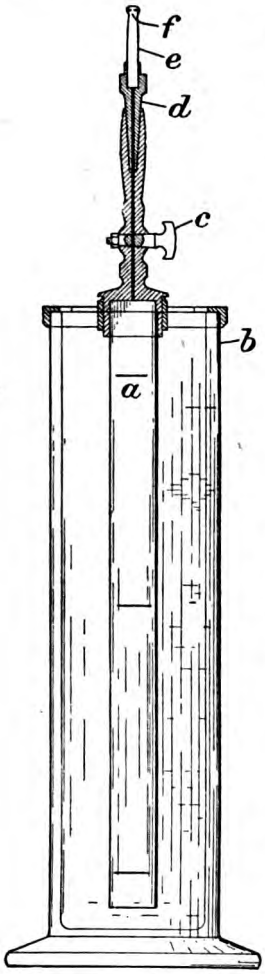

FIGURE 1.—Apparatus for determining specific gravity of natural gas.

With the Bunsen effusion method the specific gravity of a gas is determined by noting the rate at which a certain volume of the gas passes through a small orifice. The rate at which a like volume of air passes the orifice is also determined. The specific gravities are then in inverse ratio to the squares of the rates of effusion.

Some natural gas contains large percentages of nitrogen and carbon dioxide. Nitrogen has a specific gravity of 0.97 and carbon dioxide has a specific gravity of 1.53 (air = 1). If natural gas which contained these gases in large proportions was being tested and tests were not made for them, the experimenter would be misled, because of the hydrocarbons present, into believing that the gas was heavy.

In an extreme instance the senior author found that gas issuing from the ground in the State of Washington contained 98.5 per cent of nitrogen. Much of the natural gas used in Texas contains as much as 40 per cent of nitrogen, and proportions as high as 10 per cent are not uncommon.

The largest amount of carbon dioxide the authors have found in a sample of natural gas was 30 per cent. This is an unusually high percentage, but proportions as high as 10 per cent, especially in natural gas are found in California.

The natural gas in the Appalachian fields does not contain enough carbon dioxide and nitrogen to affect the specific-gravity determination in its bearing on the gasoline content. The same is true, in most cases, of natural gas found in Oklahoma and Louisiana. Some natural gas in Kansas and Texas has an uncommonly high nitrogen content.

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The authors have used the type of apparatus known as the Schilling (fig. 1) for the specific-gravity determination. It consists of a glass jar, *b*, with a metal top into which fits a brass column having suspended from its base a long graduated tube, *a*, and at its top a cock, *c*, and a ground-joint socket, *d*, into which sets a socket holding a small glass tip, *e*, closed at the top with a thin piece of platinum *f*. In this platinum is a minute hole to permit the passage of gas or air at a very slow rate. All the metal parts are nickeled. The mode of operation is as follows: The glass jar is filled with water to the top graduation mark of the tube or to a point a little above it. The tube is then withdrawn so that it may be filled with air. The cock on the standard is then closed and the tube is replaced in the jar. The cock is then opened, and the number of seconds required for the water to pass from the lowest graduation mark to the graduation mark above it is recorded with a stop watch. The tube is then withdrawn and filled with gas and the procedure repeated. The specific gravity (air = 1) is obtained by dividing the gas time squared by the air time squared. Thus, if A represents the time required for the gas to pass through the orifice, and B represents the time required for the air to pass through the orifice, the specific gravity of the gas will be represented by $\left(\frac{A}{B}\right)^2$.

SOLUBILITY TESTS.

Natural gas is soluble in various solvents, such as "mineral seal oil," "straw oil," alcohol, claroline oil, olive oil, sperm oil, and rapeseed oil, in proportions depending upon the amount of higher hydrocarbons present in the gas. In other words, the larger the content of gasoline constituents in a sample of natural gas the greater will be the solubility of that natural gas in the oil.

CHARACTERISTICS OF SOME OF THE OILS USED.

"Mineral seal oil" has the following characteristics, as determined by E. W. Dean, petroleum chemist of the Bureau of Mines.

Characteristics of "mineral seal oil."

Flash point (Pensky-Martens closed apparatus), 135° C. (275° F.).
Burning point (Pensky-Martens open apparatus), 160° C. (311° F.).
Specific gravity (water=1), 0.850, or 35° B.

The claroline oil used had the following characteristics, as determined by the authors:

Characteristics of claroline oil.

Specific gravity, 0.8667 at 15° C.
Viscosity, 4.4° Engler at 20° C.
Flash point, 152° C. (Pensky-Martens closed test).
Ignition point, 270° C. (Pensky-Martens closed test).

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Claroline oil is a distillate from petroleum and is similar, as regards its use for the purpose here described, to Russian white oil or the several substitutes that are used in this country at the present time for Russian white oil.

"Straw oil" is a petroleum distillate with a specific gravity of about 37° B.

SOLUBILITY OF NATURAL GAS IN DIFFERENT OILS.

The solubility in different oils of the natural gas, a "dry" gas, used in the city of Pittsburgh, Pa., is as follows:

Solubility in various oils of the natural gas used in Pittsburgh, Pa.

Kind of oil used as solvent.	Character of oil used.	Solubility of gas, per cent.
Claroline	Mineral	15.5
Russian white	do	16.4
Sperm	Animal	16.5
Olive	Vegetable	13.7
Rapeseed	do	14.7
Cottonseed	do	14.8
"Straw"	Mineral	17.0
"Mineral seal"	do	16.5

It was possible to check the above determinations within 0.5 per cent. Considerable uniformity as regards the solubility of the natural gas in the different oils will be noticed. In testing different samples of natural gas by the solubility method the authors have principally used claroline oil, Russian white oil, and "mineral seal oil."

SOLUBILITY OF METHANE AND ETHANE.

The solubility of pure methane in claroline was 11 per cent and in cottonseed oil 9.5 per cent. The solubility of pure ethane in claroline oil, as determined by the authors, was 68.5 per cent.

MANIPULATION OF APPARATUS FOR DETERMINING THE SOLUBILITY OF NATURAL GAS IN OIL.

An apparatus which the authors have used for determining the solubility of natural gas in oil is shown in figure 2. The principal parts are the burette *d* and the pipette *a*. The bulb *b* of the pipette has a capacity of 35 c. c. and is in communication with the bulb *a* through a three-way stopcock *c*.

Exactly 35 c. c. of oil is used in making a test, and as this quantity is not enough to fill the pipette *a* another liquid must be introduced in the pipette *a* to help fill this space and support the oil. For this purpose mercury or water may be used. To prepare the apparatus for use, enough water is poured in the reservoir bottle *i* to fill *a* and leave a small quantity in *i*. The water is forced into *a* by raising

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the bottle *i*. Next the cock *c* is turned to deliver the oil (35 c. c.) previously placed in *b* into the bulb *a*. This oil will rest above the water in *a*. The apparatus is then ready for making a determination.

The sample (100 c. c.) is transferred from the sample tube *e* to the burette *d* and accurately measured. Connection is then made between the burette and the absorption pipette, and the gas is passed into the pipette, is shaken with the oil for about three minutes, drawn

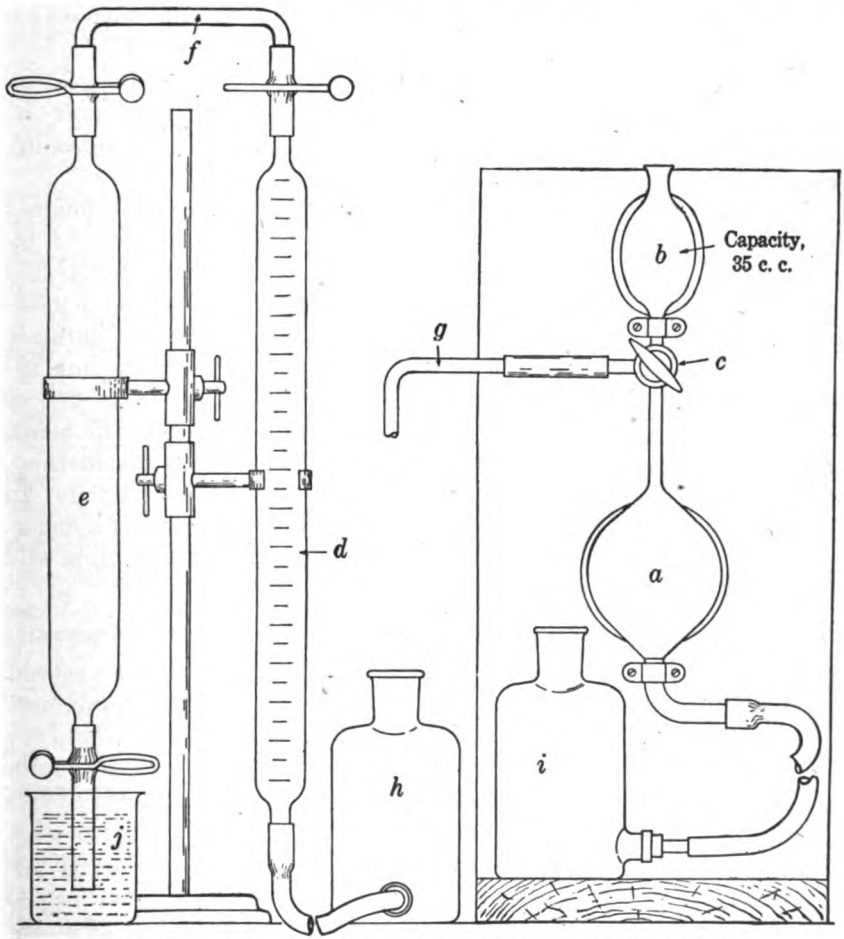

FIGURE 2.—Apparatus for determining the solubility of natural gas in oil.

into the burette, and measured. Next it is passed into the absorption pipette, again shaken with the oil, and measured. The two burette readings should check within 1 per cent. Fresh oil is used for each test.

In brief, the method consists in shaking 100 c. c. of the natural gas with 35 c. c. of oil until absorption ceases. Instead of oil, ethyl alcohol can be used, but in that case 50 c. c., not 35 c.c., should be used.

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The test is an arbitrary one and is useful only because a large number of tests have been made of natural gas from different wells, some of which is being treated to extract the gasoline content. By comparing the solubility of new samples of natural gas with the results obtained on other samples that represent gas from which gasoline can be profitably extracted, the gasoline content of the former can be estimated. The same is true of the specific-gravity test.

YIELDS OF GASOLINE CORRESPONDING TO VALUES OBTAINED IN SPECIFIC GRAVITY AND ABSORPTION TESTS.

The authors have compiled a table which gives the specific gravity and solubility in oil of different grades of casing-head gas and the yield of gasoline that is obtainable by compressing and condensing the gas.

The yields of gasoline as given in the table below, corresponding to different absorption and specific-gravity tests, were derived by testing natural gas from which gasoline was being obtained in actual plant operation. Some uncertainty exists regarding the yield of gasoline obtained, owing to the fact that such data could not be accurately obtained. At most of the plants visited, meters were not installed to measure the gas that was being treated. Hence the figures were compiled from the yield as estimated by the owner of the plant, and in some cases checked, as closely as could be done by this method, against the piston displacement of the gas-compressor cylinder. In some plants the gas was actually being measured by means of a meter. In all cases the yield represents the actual amount of gasoline sold after "weathering." The results were as follows:

Yield of gasoline from casing-head natural gas by compression method, corresponding to absorption and specific gravity tests.

Absorption by oil, per cent.	Specific gravity. (Air=1.)	Yield of gasoline, gallons per 1,000 cubic feet of gas.	Absorption by oil, per cent.	Specific gravity. (Air=1.)	Yield of gasoline, gallons per 1,000 cubic feet of gas.
16	0.64	None.	50	1.29	3.00
23	.83	1.00	48	1.37	3.50
30	.90	1.75	44	1.38	3.50
37	1.00	2.00	65	1.38	4.00
39	1.03	2.50	84	1.41	4.50
38	1.07	3.00	86	1.46	5.00
54	1.21	3.50			

RESULTS OF APPLYING TESTS TO RESIDUAL GAS.

It should be stated that both the specific-gravity test and the oil-absorption test fail when applied to residual gas from a gasoline plant because, although the results obtained will indicate high specific gravity and oil absorption, principally because of the presence of large percentages of the hydrocarbon gases ethane and propane, yet the plant will have extracted the vapors of the liquid paraffins that constitute gasoline.

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TESTING "DRY" NATURAL GAS FOR GASOLINE CONTENT.

The extraction of gasoline from so-called "dry" natural gas by the absorption method is essentially different from the method of treating "casing-head" or "wet" natural gas by the compression and condensation method. In the former method the natural gas is brought in contact with a petroleum distillate having a specific gravity of about 35° B., such as "mineral seal oil" or "straw oil," and the gasoline in the natural gas absorbed by the oil. The oil, charged with gasoline, is pumped to a steam still, by which the gasoline is recovered. The oil is then cooled and passed back into the absorber to recover another charge of gasoline. The process is continuous in that the oil is used over and over again.

By this method natural gas poor in gasoline, or "dry" gas, can be treated. There are probably no "casing-head" gasoline plants that are treating gas that yields less than about 1 gallon of gasoline per 1,000 cubic feet of gas, whereas with the absorption process a natural gas containing less than 1 pint of gasoline per 1,000 cubic feet can be treated at a profit.

For testing this "dry" gas it is desirable to use methods different from those used in testing casing-head gas, because the amount of gasoline in "dry" gas is so small.

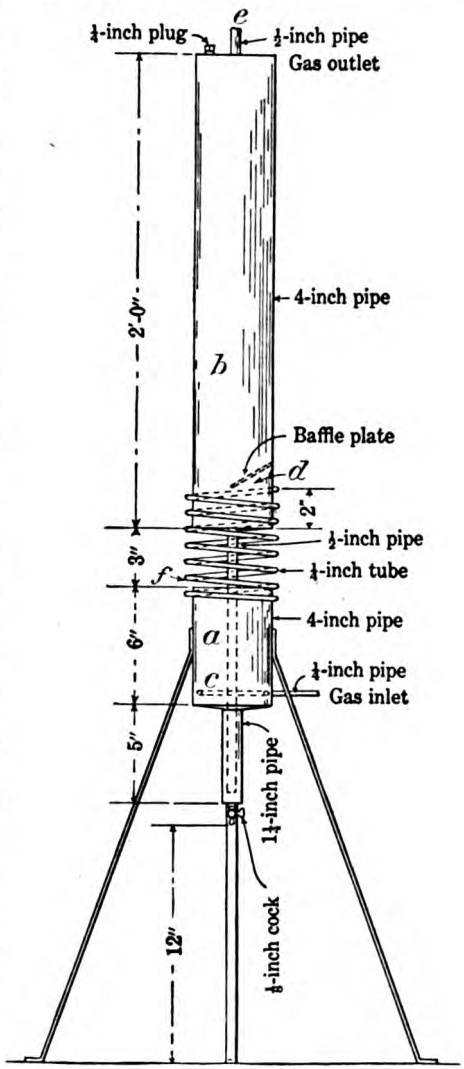

FIGURE 3.—Portable absorber for testing "dry" natural gas for gasoline content.

TESTING WITH SMALL PORTABLE ABSORBER.

One method which the authors have successfully used consists in treating the gas in a small portable absorber in a manner similar to that in which the gas is treated in a large plant. This absorber[a] is shown in figure 3. It is built on the principle of a Friedrich gas-

[a] Designed by G. A. Burrell and P. M. Biddison.

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washing bottle and consists of two lengths of 4-inch pipe, *e* and *b*, joined with a piece of ½-inch pipe and a coil of ¼-inch pipe, *f*. The lower end of the ½-inch pipe extends into a 1¼-inch pipe, as shown. The gas enters the absorber through a ¼-inch pipe which is provided with a number of small perforations that serve to break up the gas into many small streams inside the absorber. At least two absorbers in series are used in making a test.

To make a test with this absorber, the ¼-inch plug at the top is removed and 1,700 c. c. (accurately measured) of "mineral seal oil" are poured into the apparatus. The author has used quantities of oil varying from 1,500 to 2,000 c. c., about 2 quarts, in this type of absorber. Whatever the amount of oil used, it should be carefully measured. The ¼-inch plug is then screwed in place, a valve placed at *e*, and a piece of ¼-inch pipe extended from this valve to a small domestic gas meter.

Connection with the natural gas supply is made at the ¼-inch gas inlet, the valve at the gas outlet *e* is closed, a pressure gage placed at the ¼-inch plug, and the natural gas turned on until the pressure inside the absorber rises to the pressure of the line from which the gas supply is drawn.

When the pressure rises to the proper point the valve at *e* is opened slightly to release the gas through the meter. After entering the absorber the gas passes up in many fine streams through the oil in the pipe *a*, then through the pipe coil *f* into the pipe *b*, and out through the meter, where the gas is measured. The function of the ½-inch pipe extending through *a* is to provide circulation of the oil in the apparatus while the test is in progress. The function of the pipe coil *f* is to provide long and intimate contact between the oil and the gas as the gas passes through the absorber. About 100 cubic feet of gas is passed through the absorber at the rate of about 100 cubic feet per minute. The apparatus is made of iron pipe and welded to withstand high pressures.

After the gas has been passed through the absorber, about 1,000 c. c. (about 1 quart) of oil is withdrawn from the absorber through the ⅛-inch cock at the bottom, accurately measured, and submitted to distillation in a small laboratory distilling flask to separate the absorbed gasoline from the oil.

LABORATORY METHOD FOR TESTING "DRY" NATURAL GAS.

A laboratory method which the authors have used in testing natural gas for its gasoline content consists in subjecting the natural gas to a temperature of about −115° C., and then withdrawing as much of the natural gas as is possible by means of a vacuum pump. This procedure separates the natural gas into two parts, (1) the gasoline that stays behind in the liquefication bulb, and (2) the natural

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gas that is withdrawn. Then the refrigerant is removed from the gasoline, the latter allowed to vaporize, and its partial pressure measured. This pressure is proportional to the volume of gasoline vapor originally contained in the sample. A temperature of about −115° C. is used, because at this temperature the vapor pressure of the gasoline constituents is practically negligible. The vapor pressure of isobutane is 1 mm. at 115° C. and that of normal butane is 1 mm. at −100° C.[a] The principal part of the apparatus with which the laboratory freezing is performed consists of the apparatus shown in figure 4. The apparatus is exhausted of air and mercury placed in the closed gage *d*. Enough mercury is introduced so that its levels rest at the zero point of the scale when the apparatus is evacuated. Phosphorous pentoxide scattered through glass wool is placed in the bulb *c* to take up any water vapor present in the natural gas. To make a determination of gasoline vapor in natural gas the apparatus is first exhausted of air by means of a vacuum pump and the gas sample introduced. The gas is forced into the apparatus at a pressure slightly above atmospheric, and then the three-way stopcock *a* is opened to the outside air so the pressure inside the apparatus is atmospheric. The stopcock *a* is then closed and a refrigerant at a temperature of about −115° C. is placed around the bulb *b*. The authors prepare such a refrigerant by cooling gasoline with liquid air. The gasoline is placed in a Dewar flask and stirred with a test tube containing liquid air until the temperature of the gasoline, as measured with a pentane thermometer, falls to about −115° C. After waiting about 10 minutes the apparatus is connected with a good vacuum pump and as much gas removed as possible. The

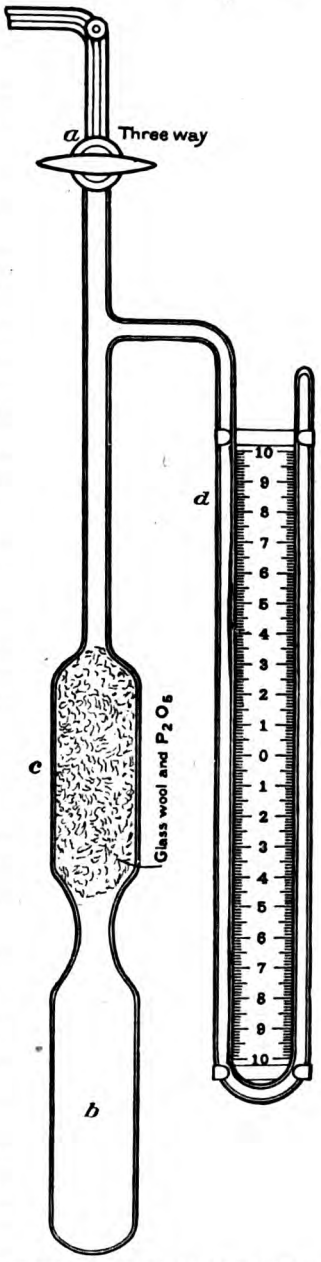

FIGURE 4.—Apparatus for determining the gasoline content of "dry" natural gas.

[a] Burrell, G. A., and Robertson, I. W., Vapor pressures of various compounds at low temperatures Technical Paper 142, Bureau of Mines, 1916, 32 pp.

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three-way stopcock is then closed and the Dewar flask containing the refrigerant removed. The frozen gasoline will immediately start to vaporize and exert a certain pressure on the mercury in the manometer tube. When the temperature in the bulb is the same as at the beginning of the experiment the mercury level in the gage is read. This pressure represents the partial pressure of the gasoline in the gas sample prior to separation. The method of converting the partial pressure of the gasoline vapor into percentage by volume is shown by the following calculations:

Determination of gasoline vapor in natural gas by the freezing method.

Original pressure (atmospheric) of sample, 740 mm.
Partial pressure of gasoline vapor, 7.4 mm.
Percentage by volume of gasoline vapor, $\frac{7.4}{740.0} \times 100 = 1.0$ per cent.

The authors have found that the percentage yield as determined by the laboratory freezing method corresponds well with the yield of gasoline in pints per 1,000 cubic feet of gas, as obtained in actual plant operation. In other words, if 1 per cent of gasoline vapor is obtained by the freezing test, 1 pint of gasoline per 1,000 cubic feet of gas treated will be obtained in an absorption plant.

ANALYSIS OF NATURAL GAS.

An analysis of natural gas for methane, ethane, carbon dioxide, and nitrogen does not provide much information regarding the gasoline content of natural gas, but such a determination is useful in showing the percentage of paraffin hydrocarbons present and in calculating the specific gravity and the heating value.

The type of apparatus with which the authors analyze natural gas for paraffin hydrocarbons, carbon dioxide, and nitrogen, the constituents of natural gas (hydrogen sulphide also is present in some natural gas) is shown in figure 5.

The pipette *a* contains potassium hydroxide solution; pipettes *b* and *d* contain alkaline pyrogallate solution; the pipette *c* is the slow combustion pipette. The burette *f* has a capacity of 100 c. c. and is graduated to 0.10 c. c.

PROCEDURE IN MAKING ANALYSIS.

Oxygen or other gas left in the horizontal capillary train from the previous analysis is displaced by drawing a few cubic centimeters of nitrogen—prepared beforehand by passing air into the pipette and absorbing the oxygen by means of the alkaline pyrogallate solution—from the pipette *d* into the burette. This mixture is then allowed to escape into the air.

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About 100 c. c. of the gas sample is then drawn from the sample container into the burette. The sample is measured in the burette against the pressure existing in the compensating tube by bringing the mercury in the manometer tube exactly to the mark *g*. The sample is then passed successively into the potassium hydroxide solution to remove carbon dioxide, and the alkaline pyrogallate solution to remove oxygen, the burette measurements being made in the same manner as with the original sample.

The residual gas left after the carbon dioxide and oxygen have been determined is discarded. The capillary connections are cleared of combustible gas by dilution with air, and 100 c. c. or slightly less of oxygen is measured into the burette and passed into the combustion pipette. About 35 c. c. of the gas sample is then drawn into the burette from the sample container and measured. The platinum wire in the combustion pipette is then heated electrically to a white heat and the gas sample passed at the rate of about 10 c. c. per minute into the combustion pipette containing the oxygen. The paraffins burn as fast as they enter, so that an explosion consequent upon the accumulation of gas and oxygen can not follow. In analyzing natural gas the authors have obtained the best results by passing the oxygen into the pipette first. When the natural gas is passed in first, the mixture does not always burn satisfactorily.

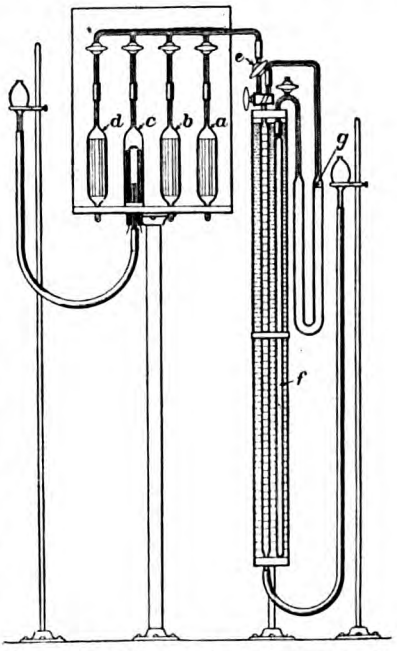

FIGURE 5.—Laboratory form of apparatus for analysis of natural gas.

After the paraffins are burned, which requires about four or five minutes, the combustion pipette is allowed to cool and the contraction in volume due to combustion is measured. The carbon dioxide produced by the combustion is determined by absorption in the potassium hydroxide solution. Then the gas is passed into the alkaline pyrogallate solution to make sure that sufficient oxygen has been present for the complete combustion of the paraffins. Some samples of natural gas, especially gas from which gasoline can be recovered, may contain such a large proportion of the higher paraffin hydrocarbons that 100 c. c. of oxygen will not be sufficient for the complete oxidation of 35 c. c. of natural gas. For such samples a smaller quantity of the gas must be used for the combustion.

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In no case is the mercury in the burette raised above the upper stopcock. The gas remaining in the capillary tubing at any stage of the analysis is brought in contact with the solutions by passing it back and forth several times between the burette and the pipette. After combustion, for instance, some carbon dioxide will remain in the capillary tubing between the combustion pipette and the burette when the gas is drawn back into the burette to record the contraction in volume. After most of the carbon dioxide has been absorbed by the potassium hydroxide the small quantity that remains in the capillary tubing is swept out of the tubing into the potassium hydroxide pipette, and the operation is repeated in order to insure the complete removal of the carbon dioxide. If this precaution is not taken an error of considerable magnitude will result. Finally the residual gas is burned again in the combustion pipette, and the amount of contraction and the volume of carbon dioxide are measured. This second burning is often necessary in order to burn the natural gas completely.

EXAMPLE OF A TYPICAL ANALYSIS.

A typical analysis with the calculations from the analytical data is given herewith.

FIRST SAMPLE.

	Burette readings, c.c.
Volume of sample taken for absorption	30.70
Volume after CO_2 absorption	30.70
CO_2 absorbed	.00
Volume after O_2 absorption	30.70
O_2 absorbed	.00

FRESH SAMPLE.

Volume of oxygen taken for combustion	74.85
Volume of sample taken for combustion	30.70
Total volume	105.55
Volume after burning	42.30
Contraction	63.25
Volume after CO_2 absorption	7.20
CO_2 contraction	35.10

Methane (CH_4) and ethane (C_2H_6) are calculated from the following theoretical equations:

$$CH_4+2O_2=CO_2+2H_2O.$$
$$C_2H_6+2.5\ O_2=2\ CO_2+3\ H_2O.$$

Let x = methane and y = ethane. Then $2x+2.5y$ = total contraction, and $x+2.0y=CO_2$ produced, whence $CH_4=84.1$ per cent, and $C_2H_6=15.1$ per cent.

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The complete analysis of the natural gas follows:

Carbon dioxide (CO_2)	[a] .0
Oxygen (O_2)	[a] .0
Methane (CH_4)	84.1
Ethane (C_2H_6)	15.1
Nitrogen (N_2)	[b] .8
	100.0

CALCULATION OF THE SPECIFIC GRAVITY.

The specific gravity is calculated from the known specific gravities of the constituents that comprise the natural gas. These are as follows:

Specific gravities of constituents of natural gas.

Constituent.	Specific gravity (air=1).
Methane	0.5545
Ethane	1.0494
Nitrogen	.9674
Carbon dioxide	1.5291
Oxygen	1.1054

The specific gravity of the natural gas sample then becomes

$$0.841 \times 0.5545 = 0.456$$
$$.151 \times 1.0494 = .158$$
$$.008 \times .9674 = .007$$
$$\text{Total} \ldots\ldots .621$$

CALCULATION OF HEATING VALUE.

The heating value of natural gas is calculated by using the heating values of the combustible constituents. These heating values follow:

Heating values of constituents of natural gas.

Constituent.	Heating value, B. t. u. per cubic foot at 760 mm. pressure.	
	0° C.	*60° F.*
Methane	1065	1008
Ethane	1861	1761

The heating value of the natural gas sample at 0° C. and 760 mm. pressure becomes

$$0.841 \times 1065 = 896 \text{ B. t. u.}$$
$$.151 \times 1861 = 281 \text{ B. t. u.}$$
$$\text{Total} \ldots 1177 \text{ B. t. u.}$$

[a] Less than 1 per cent. [b] Difference.

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MEASURING THE FLOW OF NATURAL GAS.

ORIFICE METER.

An instrument known as the orifice meter, for testing small flows of natural gas, is shown in figure 6. This instrument is simple in construction, consisting of a short 2-inch nipple, *b*, with pipe thread on one end and a thin plate disk on the other. The disk carries a 1-inch orifice, *a*, and a hose connection, *c*, for taking the pressure. The meter is especially intended for testing small gas wells and "casing-head" gas from oil wells. As a rule the flow of gas from an oil well is rather small, and it is not advisable to test the flow with a Pitot tube such as is used in testing large gas wells. In using the orifice tester, it is necessary to know the specific gravity of the gas in order to obtain the flow.

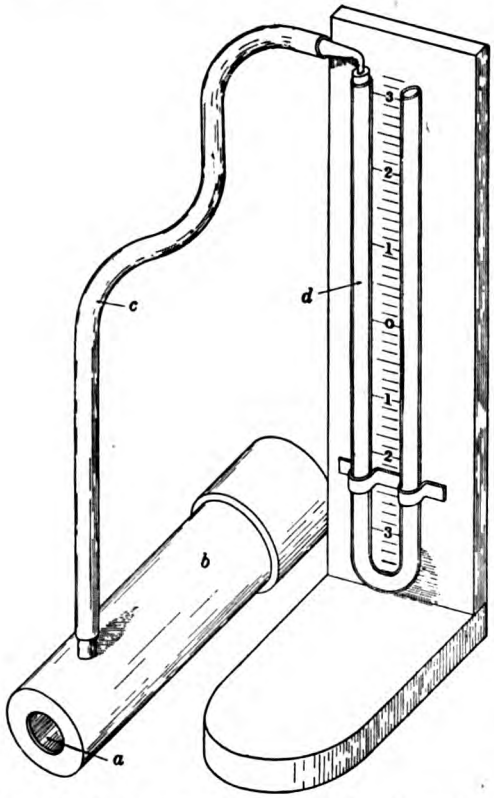

FIGURE 6.—Orifice meter for testing small flows of natural gas.

Before the orifice well tester is attached to the casing head the well should be permitted to blow into the atmosphere until the head of the gas is reduced and the flow has become normal. Then the tester is attached by simply screwing it into the end of a 3-foot length of 2-inch pipe and the pressure is read in inches of water on the siphon gage *d*. In the tables,[a] on pages 19 to 20, the flow of the well with values for the gas of different gravities is opposite the gage reading. The orifice in the instrument should be kept dry and uninjured; otherwise the gage reading will not be correct.

[a] Westcott, H. P.: Handbook of natural gas, 1915, pp. 545–548.

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Capacities of orifices for testing flows of natural gas from small gas wells and casing-head gas from oil wells.

[Temperature, 60°F.: atmospheric pressure, 14.4 pounds per square inch.]

ONE-INCH ORIFICE, IN PLATE ¼ INCH THICK.

Pressure.	Capacity, in cubic feet per 24 hours, at specific gravity of—																	
	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95	1	1.05	1.1	1.15	1.2	1.3	1.4	1.5	1.6	1.7
Inches of water.																		
1	26,440	25,440	24,500	23,660	22,920	22,220	21,600	21,020	20,520	20,010	19,560	19,120	18,720	18,000	17,320	16,750	16,200	15,720
2	37,510	36,040	34,750	33,600	32,520	31,530	30,640	29,800	29,080	28,360	27,720	27,120	26,540	25,480	24,570	23,760	22,990	22,290
3	46,440	44,640	43,000	41,540	40,240	39,020	37,940	36,880	36,000	35,130	34,320	33,550	32,850	31,560	30,400	29,370	28,440	27,600
4	52,630	50,590	48,740	47,060	45,600	44,200	42,980	41,800	40,800	39,790	38,880	38,040	37,220	35,760	34,460	33,310	32,230	31,270
5	57,880	55,630	53,610	51,790	50,160	48,640	47,280	45,980	44,880	43,770	42,760	41,830	40,940	39,360	37,920	36,620	35,470	34,410
6	63,140	60,720	58,480	56,490	54,720	53,060	51,600	50,180	48,960	47,760	46,650	45,640	44,680	42,960	41,370	39,960	38,680	37,530
7	68,110	65,470	63,090	60,910	59,040	57,210	55,630	54,120	52,800	51,500	50,320	49,220	48,190	46,320	44,610	43,100	41,730	40,480
8	73,050	70,220	67,680	65,350	63,310	61,390	59,680	58,050	56,640	55,240	54,000	52,800	51,690	49,680	47,850	46,220	44,760	43,410
9	77,680	74,680	72,000	69,500	67,340	65,270	63,480	61,720	60,240	58,800	57,430	56,160	54,960	52,800	50,880	49,170	47,610	46,200
10	82,340	79,150	76,270	73,650	71,370	69,190	67,270	65,420	63,840	62,280	60,860	59,520	58,240	55,960	53,920	52,100	50,440	48,960
11	86,680	83,320	80,300	77,540	75,120	72,840	70,800	68,880	67,200	65,560	64,080	62,660	61,320	58,920	56,780	54,860	53,110	51,520
12	90,720	87,190	84,000	81,140	78,600	76,220	74,110	72,000	70,320	68,610	67.030	65,560	64,170	61,680	59,400	57,400	55,580	53,920
Inches of mercury.																		
¼	67,200	64,600	62,300	60,100	58,200	56,500	54,900	53,400	52,100	50,800	49,600	48,600	47,500	45,700	44,000	42,500	41,100	39,900
½	95,200	91,500	88,200	85,100	82,500	80,000	77,800	75,600	73,800	72,000	70,300	68,800	67,300	64,700	62,300	60,200	58,300	56,600
1	116,600	112,000	108,000	104,300	101,000	97,900	95,300	92,600	90,400	88,200	86,200	84,300	82,500	79,200	76,300	73,800	71,400	69,300
1½	134,600	129,400	124,700	120,400	116,700	113,100	110,000	107,000	104,400	101,800	99,500	97,300	95,300	91,500	88,200	85,200	82,500	80,000
2	145,600	139,900	134,900	130,200	126,200	122,400	118,900	115,700	112,900	110,100	107,600	105,300	103,000	99,000	95,400	92,200	89,200	86,500
2½	164,900	158,500	152,700	147,500	142,900	138,600	134,700	131,000	127,800	124,700	121,800	119,200	116,600	112,000	108,000	104,300	101,000	98,000
3	178,200	171,300	165,100	159,400	154,500	149,800	145,600	141,600	138,200	134,800	131,700	128,800	126,100	121,200	116,700	112,800	109,200	105,900
3½	190,400	183,000	176,400	170,300	165,000	160,000	155,600	151,300	147,600	144,000	140,700	137,600	134,700	129,400	124,700	120,500	116,600	113,200
4	212,900	204,600	197,200	190,400	184,500	178,900	174,000	169,200	165,000	161,000	157,300	153,900	150,600	144,700	139,400	134,700	130,400	126,500
5	233,200	224,100	216,000	208,600	202,100	195,900	190,500	185,300	180,800	176,400	172,300	168,600	165,000	158,500	152,700	147,600	142,900	138,600
6	251,900	242,100	233,400	225,300	218,300	211,700	205,800	200,200	195,300	190,600	186,200	182,100	178,200	171,200	165,000	159,400	154,300	149,700
7	269,400	258,900	249,500	240,900	233,400	226,400	220,100	214,000	208,800	203,700	199,100	194,700	190,600	183,100	176,400	170,500	165,000	160,100
8	285,700	274,600	264,700	255,600	247,600	240,100	233,500	227,000	221,500	216,100	211,200	206,500	202,100	194,200	187,100	180,800	175,000	169,800
9	301,200	289,500	279,000	269,400	261,000	253,100	246,100	239,300	233,500	227,800	222,600	217,700	213,100	204,700	197,300	190,600	184,500	179,000
10	315,800	303,600	292,500	282,500	273,700	265,400	258,000	250,900	244,800	238,900	233,400	228,300	223,400	214,700	206,800	199,900	193,500	187,700
11	328,400	315,700	304,200	293,800	284,600	276,000	268,400	261,000	254,600	248,400	242,700	237,400	232,400	223,300	215,100	207,900	201,200	195,200

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Capacities of orifices for testing flows of natural gas from small gas wells and casing-head gas from oil wells.—Continued.

ONE-HALF INCH ORIFICE, IN PLATE ½ INCH THICK.

Pressure.	Capacity, in cubic feet per 24 hours, at specific gravity of—																	
	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95	1	1.05	1.1	1.15	1.2	1.3	1.4	1.5	1.6	1.7
Inches of water.																		
½.....	4,490	4,320	4,160	4,020	3,890	3,770	3,670	3,570	3,480	3,400	3,320	3,250	3,180	3,050	2,940	2,840	2,750	2,670
1.....	6,260	6,010	5,790	5,600	5,440	5,260	5,110	4,970	4,850	4,730	4,620	4,520	4,420	4,250	4,100	3,960	3,830	3,720
1½.....	7,900	7,590	7,310	7,070	6,840	6,640	6,450	6,280	6,120	5,970	5,830	5,710	5,590	5,370	5,170	5,000	4,840	4,690
2.....	9,140	8,780	8,460	8,170	7,910	7,680	7,460	7,260	7,080	6,910	6,750	6,600	6,460	6,210	5,980	5,780	5,600	5,430
2½.....	10,220	9,820	9,470	9,140	8,850	8,590	8,350	8,120	7,920	7,730	7,550	7,380	7,230	6,950	6,690	6,470	6,260	6,070
3.....	11,150	10,720	10,330	9,980	9,660	9,370	9,110	8,860	8,640	8,430	8,240	8,060	7,890	7,580	7,300	7,050	6,830	6,630
3½.....	12,020	11,550	11,130	10,750	10,410	10,100	9,810	9,550	9,310	9,090	8,880	8,680	8,500	8,170	7,870	7,600	7,361	7,140
4.....	12,800	12,290	11,850	11,440	11,080	10,750	10,450	10,170	9,910	9,670	9,450	9,240	9,050	8,690	8,380	8,090	7,840	7,600
4½.....	13,480	12,950	12,480	12,050	11,670	11,320	11,000	10,710	10,440	10,190	9,950	9,730	9,530	9,160	8,820	8,520	8,250	8,010
5.....	14,130	13,570	13,080	12,640	12,230	11,870	11,530	11,230	10,940	10,680	10,430	10,200	9,990	9,600	9,250	8,930	8,650	8,390
5½.....	14,690	14,110	13,600	13,130	12,720	12,340	11,990	11,670	11,380	11,100	10,850	10,610	10,380	9,980	9,610	9,290	8,990	8,720
6.....	15,210	14,620	14,080	13,610	13,170	12,780	12,420	12,090	11,780	11,500	11,230	10,990	10,760	10,330	9,960	9,620	9,310	9,040

THREE-EIGHTHS INCH ORIFICE, IN PLATE ⅜ INCH THICK.

½.....	2,270	2,180	2,100	2,030	1,970	1,910	1,850	1,810	1,760	1,720	1,680	1,640	1,610	1,540	1,490	1,440	1,390	1,350
1.....	3,460	3,320	3,200	3,090	3,000	2,910	2,820	2,750	2,680	2,670	2,550	2,500	2,450	2,350	2,260	2,190	2,120	2,050
1½.....	4,310	4,140	3,990	3,860	3,730	3,620	3,520	3,420	3,339	3,260	3,180	3,110	3,050	2,930	2,820	2,730	2,640	2,560
2.....	4,830	4,640	4,470	4,320	4,180	4,060	3,940	3,840	3,740	3,650	3,560	3,490	3,410	3,280	3,160	3,950	2,960	2,870
2½.....	5,400	5,190	5,000	4,830	4,680	4,540	4,410	4,290	4,186	4,080	3,990	3,900	3,820	3,670	3,540	3,420	3,310	3,210
3.....	5,770	5,550	5,350	5,170	5,000	4,850	4,720	4,590	4,474	4,370	4,260	4,170	4,080	3,920	3,780	3,650	3,540	3,430
3½.....	6,290	6,050	5,830	5,630	5,450	5,290	5,140	5,000	4,875	4,760	4,650	4,550	4,450	4,270	4,120	3,980	3,850	3,740
4.....	6,650	6,390	6,160	5,950	5,760	5,590	5,430	5,280	5,152	5,030	4,910	4,800	4,700	4,520	4,350	4,210	4,070	3,950
4½.....	7,210	6,930	6,680	6,450	6,240	6,060	5,890	5,730	5,585	5,450	5,330	5,210	5,100	4,900	4,720	4,560	4,410	4,280
5.....	7,680	7,380	7,110	6,870	6,650	6,450	6,270	6,100	5,946	5,800	5 670	5,540	5,430	5,210	5,020	4,850	4,700	4,560
5½.....	8,100	7,790	7,500	7,250	7,020	6,810	6,620	6,440	6,278	6,130	5,980	5,850	5 730	5,510	5,310	5,130	4,960	4,810
6.....	8,290	7,970	7,680	7,420	7,180	6,970	6,770	6,590	6,423	6,270	6,120	5,990	5,860	5,630	5,430	5,240	5,080	4,930

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PITOT TUBE FOR TESTING OPEN FLOW OF GAS WELLS.

The most accurate way of testing the flow of a gas well is by means of the Pitot tube, which is an instrument for determining the velocity of flowing gas by means of its momentum. The instrument, as shown in figure 7, usually consists of a small tube, with one end bent at right angles, which is inserted in the flowing gas, just inside the

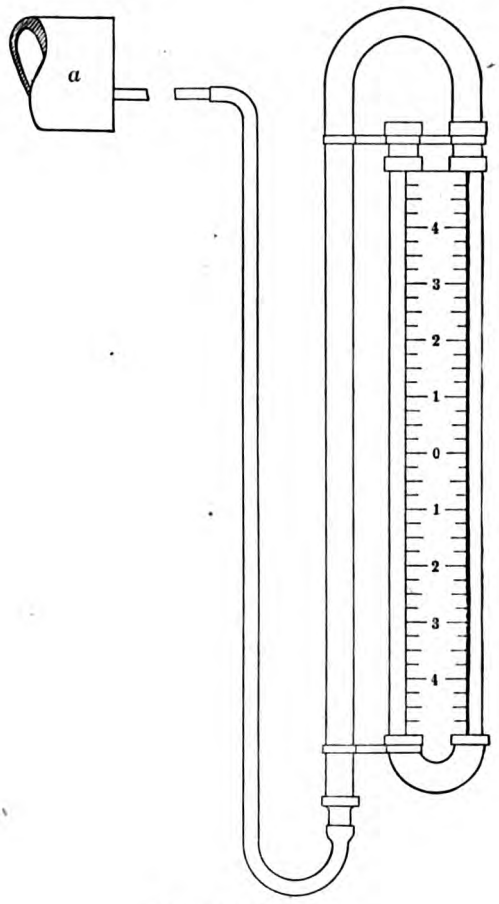

FIGURE 7.—Pitot tube.

pipe or tubing *a*, at a point between one-third and one-fourth of the pipe's diameter from the outer edge of the pipe. The plane of the opening in the tube is held at right angles to the flowing gas. At a convenient distance, varying from 1 to 2 feet, an inverted siphon or U-shaped gage, usually half filled with mercury or water, is attached to the other end. If the pressure of the flow is more than 5 pounds per square inch, a pressure gage is required.

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In small-sized wells with a flow of not more than 4,000,000 cubic feet per 24 hours, a 12-inch U-gage with water can be used; for flows ranging from 4,000,000 to 15,000,000 feet, mercury in a 12-inch U-gage; for 15,000,000 to 35,000,000 feet, a 50-pound spring gage, and for more than 35,000,000 feet, a 100-pound spring gage should be used. The foregoing figures are based on a 6-inch hole.

For convenience, a scale graduated from the center in inches and tenths of an inch is attached between the two limbs of the U-gage. The distance above and below this center line at which the liquid in the gage stands should be added, the object being to determine the exact distance between the high and low side of the fluid in inches and tenths of an inch.

The top joint of the tubing or casing should be free from fittings for a distance of 10 feet below the mouth of the well where the test is made. The test should not be made in a collar or gate or at the mouth of any fitting. The well should be blown off at least three hours prior to making the test.

After the velocity pressure of the gas flowing from the well tubing has been determined in inches of water, inches of mercury, or pounds per square inch, as outlined above, the corresponding flow may be obtained from the following table.[a] The quantities of gas stated in the table are based on a pressure of 4 ounces above atmospheric, or 14.65 pounds per square inch absolute pressure, a flowing temperature of 60° F., a storage temperature of 60° F., and a specific gravity of 0.60 (air = 1). If the specific gravity is other than 0.60 the flow should be multiplied by $\sqrt{\frac{0.60}{\text{specific gravity of gas}}}$.

[a] Westcott, H. P., Handbook of natural gas, 1915, pp. 176, 177.

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Table for determining flow of gas wells by means of Pitot tube.

[Figures show the rate of flow of gas of 0.6 specific gravity from gas well tubing of different sizes in cubic feet per 24 hours, for different pressures.]

Pressure.			Volume of gas, in cubic feet per 24 hours, discharged through—				Pressure.			Volume of gas, in cubic feet per 24 hours, discharged through—			
Inches of water.	Inches of mercury.	Pounds per square inch.	1-inch tubing.	2-inch tubing.	3-inch tubing.	4-inch tubing.	Inches of water.	Inches of mercury.	Pounds per square inch.	1-inch tubing.	2-inch tubing.	3-inch tubing.	4-inch tubing.
0.10			11,880	47,520	106,920	190,080		5.59	2.75	321,000	1,284,000	2,889,000	5,136,000
.20			17,136	68,544	154,224	274,176		6.10	3.	340,200	1,360,800	3,061,800	5,443,200
.30			20,568	82,272	185,112	329,088		6.61	3.25	354,120	1,416,480	3,187,080	5,665,920
.40			23,520	94,080	211,680	376,320		7.11	3.50	367,680	1,470,720	3,309,120	5,882,880
.50			26,544	106,176	238,896	424,704		7.62	3.75	380,400	1,521,600	3,423,600	6,086,400
.60			29,112	116,448	262,008	465,792		8.13	4.00	392,880	1,571,520	3,535,920	6,286,080
.7			31,440	125,760	282,960	503,040		8.64	4.25	405,000	1,620,000	3,645,000	6,480,000
.8			33,624	134,496	302,616	537,984		9.15	4.50	416,640	1,666,560	3,749,760	6,666,240
.9			35,640	142,560	320,760	570,240		9.65	4.75	428,280	1,713,120	3,854,520	6,852,480
1.0			37,320	149,280	335,880	597,120		10.16	5.00	439,920	1,759,680	3,959,280	7,038,720
1.25			41,712	166,848	375,408	667,392		12.20	6	476,040	1,904,160	4,284,360	7,616,640
1.5			45,960	183,840	413,640	735,360			7	517,320	2,069,280	4,655,880	8,277,120
1.75	0.12		49,680	198,720	447,120	794,880			8	542,400	2,169,600	4,881,600	8,678,400
2.0	.147		53,136	212,544	478,224	850,176			9	569,640	2,278,650	5,126,760	9,114,240
2.5	.184		59,400	237,600	534,600	950,400			10	595,560	2,382,240	5,360,040	9,528,960
3.0	.22	.108	65,088	260,352	585,792	1,041,408			11	621,960	2,487,840	5,597,640	9,951,360
3.5	.257	.126	70,272	281,088	632,448	1,124,352			12	642,600	2,570,400	5,783,400	10,281,600
4.0	.294	.144	75,120	300,480	676,080	1,201,920			13	664,680	2,658,720	5,982,120	10,634,880
4.5	.331	.162	79,704	318,810	717,336	1,275,264			14	683,880	2,735,520	6,154,920	10,942,080
5.0	.368	.18	84,000	336,000	756,000	1,344,000			15	703,080	2,812,320	6,327,720	11,249,280
6.	.441	.216	92,016	368,060	828,144	1,472,256			16	721,080	2,884,320	6,489,720	11,537,280
7.	.515	.252	99,360	397,440	894,240	1,589,760			17	738,120	2,952,480	6,643,080	11,809,920
8.	.588	.288	106,272	425,088	956,448	1,700,352			18	753,960	3,015,840	6,785,640	12,063,360
9.	.662	.324	112,656	450,624	1,013,904	1,802,496			20	785,520	3,142,080	7,069,680	12,568,320
10.	.736	.36	118,800	475,200	1,069,200	1,900,800			22	803,280	3,213,120	7,229,520	12,852,480
11.	.8	.396	125,160	500,640	1,126,440	2,002,560			25	854,880	3,419,520	7,693,920	13,678,080
12.	.88	.432	130,128	520,512	1,171,152	2,082,048			30	910,680	3,642,720	8,196,120	14,570,880
	1.02	.5	138,960	555,840	1,250,640	2,223,360			35	960,960	3,843,840	8,648,640	15,375,360
	1.52	.75	170,280	681,120	1,532,520	2,724,480			40	1,006,680	4,026,720	9,060,120	16,106,880
	2.03	1.00	196,680	786,720	1,770,120	3,146,880			45	1,046,520	4,186,080	9,418,680	16,744,320
	2.54	1.25	219,960	879,840	1,979,640	3,519,360			50	1,081,920	4,327,680	9,737,280	17,310,720
	3.05	1.5	240,720	962,880	2,166,480	3,851,520			60	1,137,120	4,548,480	10,234,080	18,193,920
	3.56	1.75	259,920	1,039,680	2,339,280	4,158,720			75	1,223,400	4,893,600	11,010,600	19,574,400
	4.07	2.00	272,640	1,090,560	2,453,760	4,362,240			90	1,304,400	5,217,600	11,739,600	20,870,400
	4.57	2.25	294,600	1,178,400	2,651,400	4,713,600			100	1,336,920	5,347,680	12,032,280	21,390,720
	5.08	2.50	310,800	1,243,200	2,797,200	4,972,800							

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For pipe diameters other than those given in the preceding table, the following multipliers should be applied to the figures for 1-inch tubing given in the table.

Multipliers for pipe diameters ranging from 1½ to 12 inches.

Diameter of pipe, inches.	Multiplier.	Diameter of pipe, inches.	Multiplier.	Diameter of pipe, inches.	Multiplier.
1½	2.25	5	25	8	64
2½	6.25	5⅝	31.64	8½	68
4¼	18	6	36	9	81
4⅝	21.39	6¼	39	10	100
		6⅝	43.9	12	144

SUMMARY.

Natural gas to be treated by compression and condensation methods may be tested for its gasoline content by determining the specific gravity of the gas and the percentage of absorption in oil. The quantity of gasoline that may be obtained from natural gas ranging in specific gravity from 0.64 to 1.46 varies from zero to 5 gallons per 1,000 cubic feet of gas tested. The yield corresponding to the percentage of the gas absorbed in oil varies from zero for an absorption of 16 per cent to 5 gallons for an absorption of 86 per cent.

So called "dry gas" can be tested for treatment by the absorption process, a method that is a duplicate on a small scale of the large-scale practice. The method consists in absorbing the gasoline in "mineral seal oil" by passing a measured amount of the gas through the oil in a portable absorber and then distilling the absorbed gasoline out of the oil.

Another method that is essentially a laboratory method consists in freezing the gasoline out of the natural gas at a temperature of about −115° C.

The flow of gas from a well may be determined by the use of a Pitot tube or an orifice meter; the flows of less than 15,000 feet in 24 hours may be measured directly by domestic meters.

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